Defense Science and Technology Strategy

September 1994

DEFENSE

SCIENCE AND TECHNOLOGY

STRATEGY

September 1994

Department of Defense

Director, Defense Research and Engineering

PREFACE

The technological superiority of U.S. forces contributes to reduced casualties and quicker victories. This superiority must be maintained today under circumstances profoundly different from those of even the recent past. During the Cold War, we faced a technologically competent, largely predictable single adversary. We measured our technological progress and rate of modernization against his. Now the Cold War is over. U.S. defense resources have been reduced accordingly. We must increasingly turn to commercial or commercially derived products for our needs, taking advantage of both economies of scale and of cutting edge technologies that are now increasingly to be found in the commercial sector. And if we are finding solutions in the commercial sector, others may, as well. That means we must also develop approaches that will enable us to maintain our edge even when our potential adversaries have access to the same basic technology. We will devote attention to higher-cost, defense-financed, defense-dedicated technological solutions only in those instances, such as nuclear submarines or high-performance jet engines, where there is no commercial counterpart.

In addition to these changes, we find that our society is placing greater demands on the producers of technology. We have entered an age of technology integration. Society requires that our technology not only work, but that it be environmentally sound and economically productive.

The Department of Defense has developed a number of ways of dealing with these new, sometimes conflicting currents. We are involving the operational military user earlier and more often in technology development to hasten the fielding of useful systems and shorten the time it takes to develop doctrine for their use. We are directing technological innovation not only to improve system performance, but -- for the first time -- to reduce cost and improve production. We are concentrating our resources wherever possible on dual use technology, that is technology that has both military and commercial uses.

These and other innovations comprise our Defense Science and Technology Strategy, and its accompanying Science and Technology Plan, which is the blueprint for executing the strategy. Together, they present a coherent, well-thought out plan for keeping our national security technological edge in a time of profound change.

John M. Deutch
Deputy Secretary of Defense

TABLE OF CONTENTS

I. VISION

Develop and transition superior technology to enable affordable, decisive military capability and to enhance economic security.

Technological superiority is a principal characteristic of our military advantage. It is the objective of the DoD Science and Technology (S&T) Program to develop options for decisive military capabilities based on superior technology.

Dramatic changes affect our national security posture. With the end of the Cold War have come heightened threats of regional conflicts, proliferation of weapons of mass destruction, and increased demand for peacekeeping and humanitarian missions. At the same time, force structure has been reduced, and development and production of new weapon systems has been sharply curtailed.

In addition, our national economic security is challenged. Shrinking defense budgets dictate that we can no longer afford defense-funded, defense-unique solutions to our requirements. Furthermore, for an increasing number of defense-critical technologies, commercial demand, not defense demand, drives technical progress.

The Defense Science and Technology Strategy is responsive to new threats, challenges, demands, and opportunities. Technological superiority remains essential, but it is no longer sufficient. Our vision contains two new elements that complement and extend it: affordable weaponry and enhanced economic security. Together they demand that the DoD pursue technology in new ways. We must utilize the economies of scale and technology innovation of commercial industry. We must improve productivity and reduce costs. Above all we must assure technological superiority.

> "We are not the only nation with competence in defense science and technology. To sustain the lead which brought us victory during Desert Storm,...recognizing that over time other nations will develop comparable capabilities, we must...invest in the next generation of defense technologies."
>
> — William J. Perry

II. S&T CONTRIBUTIONS TO MILITARY NEEDS

"Technological innovation is an invaluable combat multiplier, both for the near-term and the future."

Admiral William A. Owens
Vice Chairman, Joint Chiefs of Staff

Military needs must determine what aspects of science and technology the Department pursues, and with what priority. It is the warfighter who enunciates those needs in this post-Cold War environment of widespread local warfare, potential for major regional conflicts, proliferation of weapons of mass destruction, and peacemaking operations.

The Joint Staff and the Joint Requirements Oversight Council have identified five Future Joint Warfighting Capabilities most needed by the U.S. Combatant Commands. These needs, coupled with technological opportunity, guide S&T investment decisions The five Future Joint Warfighting Capabilities are:

1. To maintain near perfect real-time knowledge of the enemy and communicate that to all forces in near-real time.
2. To engage regional forces promptly in decisive combat, on a global basis.
3. To employ a range of capabilities more suitable to actions at the lower end of the full range of military operations which allow achievement of military objectives with minimum casualties and collateral damage.
4. To control the use of space.
5. To counter the threat of weapons of mass destruction and future ballistic and cruise missiles to the CONUS and deployed forces.

Each of the five Warfighting Capabilities is discussed in terms of deficiencies that need to be overcome and the technologies that must be delivered to attain that Capability, and in terms of technological opportunities to be exploited.

The Joint Staff Future Joint Warfighting Capabilities

1. To maintain near perfect, real-time knowledge of the enemy and communicate that to all forces in near-real time. Warfighters need to know

where the enemy is, what his capabilities are, where friendly forces are, and what range of actions each could execute. In addition, warfighters need meteorological, topographical, geographical, and political data. The three major aspects of the battlefield information system that provide this information—surveillance, information management, and communication—all require improvement.

Ground, sea, air, and space sensors are arrayed in the theater and globally. Yet, needed information may not be available. Sensor improvements are required: improved resolution, dynamic range, and all-weather performance are continuing challenges. Near perfect, real-time knowledge requires theater surveillance supplemented by national intelligence means, particularly for sensing defended hostile terrain. Unmanned air vehicle approaches are particularly promising for the surveillance of defended hostile terrain. Major technical challenges include endurance, stealth, and communications. Timely battle damage assessment and extensive, up-to-date knowledge of enemy forces and assets—e.g., buried and mobile targets as well as communications networks—are required.

Assured, reliable identification of friendly versus adversary forces must be developed. Detecting and classifying threats and targets remains an extraordinarily difficult problem. Air targets must be detected and classified before a fighter closes to ideal firing range; land systems (tanks, artillery, and soldiers with portable launchers) must be detected when hidden in foliage or behind land forms, as must underwater weapons from submarines to mines in the ocean and near shore environment. Improvement is required in terms of range, speed of classification, and accuracy of location. The task of separating friends from foes is made more difficult when both use the same kinds of equipment, as is increasingly common in many parts of the world.

Information management systems must deliver information in near-real time through links of widely varying capacities, traffic loads, and jam resistance. While this is a technical challenge, a more fundamental problem is the dissemination of needed information—in contrast to raw data—at all appropriate command levels and within time constraints determined by commanders. Communications networks linking large numbers of users into local and global networks with appropriate capacity remains a challenge for conventional global surface and air battlefield surveillance. At the local battlefield level, secure reliable wide band communications and information management to match the data to the user—from the individual to the platform commander—need much improvement. Reliable, configurable networks, adapted to the contingency, must be rapidly deployable.

2. *To engage regional forces promptly in decisive combat, on a global basis.* Prompt reaction to regional conflicts has two components: global

mobility—including both lift and lightening what we carry—and decisive combat. Recent improvements in lift have been modest. Yet, incremental improvements can have substantial cost benefit where new platforms are to be acquired. In airlift, improvements are sought in propulsion and avionics. Substantial strides have been made in reducing the weight of Army and Marine forces. Technological developments promise still greater improvements, which will lead directly to increasing the size of the force that can be brought to a conflict in a short period of time.

Major new platforms are exceedingly complex systems, both technically challenging and expensive; witness the C-17 and SSN-21. Modern computer-based design and virtual prototyping capabilities, combined with improved numerical modeling could, however, lead to venturesome new approaches to reducing costs. Similarly, significant improvements in component weight and volume, or in performance, may help retain or recapture market share for U.S. industry, leading in turn to more affordable military platforms.

Once in theater, the objective is *decisive* combat. Assured, rapid neutralization of mines must be developed to enable forced littoral entry by expeditionary forces. Near perfect, real-time knowledge of the battle environment enables rapid recognition and tracking of threats as they become visible, and improved precision strike from extended range. Precision strike has been a major S&T objective for several years, and is likely to remain high priority for many more; the ability to destroy only selected targets remotely and with precision changes the nature of conflict. It simultaneously stresses surveillance, guidance and control, and lethality technologies. Fire-and-forget weapons whose guidance and control do not require manual assistance are important.

Unmanned vehicle and deployable sensors in the air, on land, and undersea provide attractive options in dangerous or exposed operations. Unique theater-specific challenges, such as the North Korean caves and tunnels that harbor artillery and other assets, demand innovative solutions. These requirements are even more difficult to meet when the target is buried and hardened. The U.S. must develop and exploit sensors capable of locating buried targets and munitions capable of penetrating the earth deeply enough to be lethal against hardened facilities.

3. To employ a range of capabilities more suitable to actions at the lower end of the full range of military operations which allow achievement of military objectives with minimum casualties and collateral damage. At the lower end of military operations, the principal challenge is minimum casualties and controlled collateral damage. This requires improved intelligence and targeting; it reinforces the importance of maintaining near perfect, real-time knowledge of the battle environment. Precise targeting and controlled

destruction, particularly in settings where enemy combatants mingle with civilians, will lessen collateral damage and casualties.

Another aspect of low end operations is Special Operations. Highly trained military teams require technology to assist in clandestine infiltration, comprehensive local surveillance, and tailored weapons.

Peacekeeping, peacemaking, and humanitarian aid requires management of people: refugees, neutrals, and potentially hostile forces. In some cases, distinctions between them are difficult to make. The capability to neutralize, disable, disorient, or confuse without lasting effects should be an option. Denial of mobility, communications, and resupply can be wielded as a military capability, yet yield minimal casualties and collateral damage.

Exposure of U.S. personnel to hostile action and to dangerous environments is intrinsic to low end operations. Minimization of casualties requires physical and bio-chemical protection of U.S. forces, prompt and effective battlefield medical care, and the prevention of infectious disease. Information management technologies offer opportunities for improved battlefield care; biotechnologies have promise both for trauma care and for disease control.

4. *To control the use of space.* U.S. security faces a new challenge arising from the increasing number of countries with access to space systems that can enhance military capabilities. Desert Storm demonstrated the benefit of space assets for communications, navigation, weather monitoring, threat warning, and intelligence gathering. In Desert Storm the U.S. had a substantial advantage in situational awareness. Without control over the access to space, that advantage is lost.

Complicating the issue is the increased reliance by the U.S. military and our allies on commercial systems, particularly communications satellites, and the increased reliance by commercial industry on military systems, such as the Global Positioning System. The S&T challenge is to provide sufficiently precise and tailored options for the control of space to ensure that the U.S. has information dominance. There must be a range of alternatives suitable for use in a variety of political contexts.

Maintenance of our ability to have uninterrupted access to information from space is essential. We must protect our own space systems against what will certainly be an increasing diversity of threats. This calls for a broad spectrum of space system survivability measures to protect all aspects of our exploitation of space -- our satellites, their communications links, ground stations, and data dissemination capabilities. Hardening, shielding, and both physical and communications agility require continuous improvement. Rapid

and precise identification and tracking of adversary space assets is critical to prompt accurate execution of counterspace missions.

5. To counter the threat of weapons of mass destruction and future ballistic and cruise missiles to the CONUS and deployed forces. Weapons of mass destruction (WMD), ballistic missiles, and cruise missiles present a wide range of threats. The Ballistic Missile Defense Organization has a well-defined program to counter the ballistic missile threat to both the CONUS and in-theater. Chemical and biological WMDs are potentially even more stressful targets because of the collateral damage from release of their agents during even a "successful" defense. There is a premium on destruction before and during the initial stages of launch. Better detection of and defense against biological agents, however they are delivered, is needed today. Detection and deterrence of the deployment of weapons of mass destruction calls for deployable unattended sensors and techniques for detecting and evaluating the existence of WMD manufacturing capability.

The new security environment poses additional and more difficult problems of detection. These include finding components of and production capabilities for weapons of mass destruction. The challenge starts with locating and tracking items that by themselves may be harmless, but in combination are threats; and with identifying and deciphering nominally civilian enterprises that may, in reality, be weapons related. It extends to the battlefield identification and assessment of damage capacity of alert and launched weapons so that the proper level of counterforce can be exerted promptly.

Cruise missiles, another growing threat in the post-cold war era, require a layered defense. They stress sensor technology, as well as information management and data linking to coordinate responses. Anti-missile missile agility, and fusing against fast moving, stealthy, small targets are also required.

Summary

The opportunities and challenges derived from this parsing of the JCS Capabilities fall logically into four categories. First, information—its collection, management, dissemination and exploitation—can significantly leverage our military capabilities. In some cases the performance of current systems can be rapidly upgraded and enhanced. We must be able to defend out systems and disable those of an adversary. Second, the Joint Staff uses terms such as "global", "all forces", and "full range of military operations"; these imply that the S&T program must support evolutionary upgrades across the full inventory of systems. There are no magic solutions. Success requires vigilance across a broad spectrum of technologies in order to improve our military capabilities and match the improvements of our potential adversaries.

Completeness in the exploration of technologies is necessarily a cornerstone of the S&T program.

Third, there are unsolved or pervasive challenges, where significant advances could change the scale or pace of warfare, or where lack of progress could enable opposing forces to thwart U.S. objectives. Examples include information access, mobility, precision strike, underwater surveillance, and human battlefield performance. Finally, the Joint Staff emphasize two new challenges posed by the post-Cold War security environment. One is non- and counter-proliferation, in particular detection and identification of proliferation activities, and the second is protection and ennancement of the individual and small units, together with options for the management of people for use in peacemaking and peacekeeping operations.

III. STRATEGIC INVESTMENT PRIORITIES

We use the five Future Joint Warfighting Capabilities from the Joint Staff as the seminal definition of the future needs of our operational forces. However, S&T program content is constrained by limited budgets. At any point in time there are a number of technologies that are ripe for exploitation and application. These technologies must be explored even when budgets are limited and other opportunities cannot be pursued. Before discussing specific technologies, however, two generic priorities require discussion: dual use technology development and affordability. Both are new to the defense S&T program. Both have high priority.

Dual Use. Defense-unique industries cannot be sustained by current and future defense budgets, in general. Also, technologies critical to national security are being developed and matured commercially and internationally. Therefore, in the future DoD must rely—to the extent possible—on the same industrial base that builds commercial products. Both reduced cost of product and technological sophistication will result. A common commercial and defense industrial base will serve defense needs better, and it will enhance U.S. economic competitiveness. Industry will have the benefit of combined, larger markets.

The S&T program contributes to building the common industrial base by utilizing commercial practices, processes, and products, and by developing, where possible, technology that can be the base for both military and commercial products. This attention to the commercial aspects of technology requires a change in the management of science and technology.

Affordability. Budget decreases compel the consideration of affordability as an integral part of the science and technology program. The defense budget for acquiring new systems and modernizing old system is reduced by more than 60 percent over a decade. Technology can and must ensure that the military departments can buy more for less. In past times the threat demanded and the budget permitted the S&T program to focus single-mindedly on increased performance along all warfighting dimensions such as fighter aircraft speed, cold weather equipment endurance, satellite electronics radiation hardness, unattended air vehicle loiter time, artillery shell throw distance, and warhead lethality. Today, materiel and systems must be developed at a lower cost, be longer-lived, and be incrementally enhanced in capability through planned upgrades. The potential of technology to contribute is great; consider:

- simulation to improve training and readiness, thus enabling a smaller force to be more effective,
- technology to improve production process and reduce fabrication cost and elapsed time,
- sensors and materials that monitor wear, stress and fatigue and reduce need for maintenance and maintenance personnel, and
- components and subsystems that improve the performance and extend the useful operational lives of current systems.

And as in the past, technology that increases the effectiveness of systems means that more can be accomplished with less materiel. Total cost can be reduced.

There is a general need to develop materials that are less costly to form or mold into needed shapes; mature the integrated product and process concepts that permit us to tailor, modify, and optimize the manufacturing process; develop sensors and materials that will detect and advise of the need for maintenance, thereby permitting longer intervals between maintenance cycles. Affordability is a pervasive requirement that will be emphasized throughout the S&T program.

Technology Priorities

Analysis of the future capabilities that the Combatant Commands most need and the scientific and technological opportunities that exist today leads to establishing several technology areas as requiring high priority investment. Emphasis will be placed on the following areas: information science and technology, modeling and simulation, and sensors.

Information Science and Technology. Information technologies are dramatically changing the battlefield. They enable better performance of current platforms, weapons, sensors, and people. Today, electronics and software add capability to almost every complex system. Information technologies are the basis for continual improvements in communications; intelligence gathering, analysis and distribution; precision strike; platform, vehicle, and weapon control; battlefield situational awareness; command and control; sensor data processing; and human performance. In addition, these technologies improve the capability and the delivery of support services such as logistics, medical care, and transportation. They figure importantly in the research and development process itself.

Increasingly and ideally, each individual warfighter has the near-real-time benefit of information compiled from the knowledge, skill, and capability of the full combatant force and civilian assets of the U.S. The individual warfighter is empowered by information drawn from the global system of which he or she is a part. Advanced information architectures—the knitting

together of a system which can make the whole vastly more effective than the sum of its component parts—is a distinctly U.S. advantage. It must be exploited. Technology is enabling the creation of a robust information system; doctrine and command structures will determine how it is exploited.

Information systems are a military asset that must be protected. Their vulnerabilities, failure modes, and robustness must be understood in order to defend against attacks on them and to attack the information systems of an adversary.

Information technologies also provide the greatest opportunity for technology insertion at minimum cost. They facilitate the introduction of new sensors and sub-systems. Software, for example, can enable the integration of disparate components into a functional whole.

Leadership in information science and technology is critical to achieving the Future Joint Warfighting Capabilities. It is crucial to achieving those capabilities with comparative technological superiority over potential adversaries. That leadership is also crucial to the future economic security of the U.S. The largest increase in Gross National Product over the past decade has come from information technology products and services. This is expected to continue.

The strategic investment in information science and technology must span the spectrum from scientific exploration, for example in the use of light rather than electricity for certain communications, to later stage technology exploration, for example in ceramic packaging or software tools for building military decision aids.

Modeling and Simulation. Modeling and simulation holds the promise of broad applicability; the benefits are both cost reduction and new capability. Most military applications of modeling and simulation to date have been for training. This technology provides a fast, effective, and inexpensive means to prepare individuals and units for possible encounters or conflicts. Its contribution to assuring readiness in a cost-effective way is increasing. Training applications overlap with mission rehearsal and mission planning. They will merge even more in the future so that models and simulations will be warfighting systems, not merely at-home training systems.

Modeling and simulation can be applied to more than just training. It can be used during concept formulations to expand the range of technical, operational, and system alternatives evaluated. The technology can augment test and evaluation of systems, and hasten manufacturing with reduced cost. Simulations can be the basis for planning and decision aids to stretch the ability of commanders to train, to plan, and to employ their forces.

Challenges remain in the areas of virtual reality; use of extant communications; linking virtual simulations with constructive wargames and live ranges; variable resolution of simulated entities; realistic semi-automated forces; validation that a simulation performs as specified; verification that a model or simulation sufficiently represents reality; and accreditation of a model or simulation as a suitable basis for exploring a particular issue.

Sensors. It is sensors that provide data about objects or physical phenomena of importance on the battlefield. To know, to know more, and to know it sooner than the enemy is to have the advantage. The sensor technology program is broadly based; it exploits the full range of the electromagnetic spectrum. Applications include situational awareness, target identification and discrimination, and targeting.

One objective is to deny the enemy sanctuary. Radar sensors that can detect concealed ground targets when concealed by foliage and camouflage are important, as are advanced acoustic, magnetic, and laser sensors to detect and locate submarines and mines in shallow water. Sensors that can penetrate the earth to detect buried structures and mines are of critical importance.

Challenging requirements for sensors to aid in countering weapons of mass destruction must be met. First, the U.S. needs to be aware of the existence of plants capable of creating nuclear, biological, or chemical materials. Second, the U.S. needs to monitor—typically at long distances—the output of such plants and then track the movement and stockpiling of materials. Third, the U.S. needs better sensors to detect and identify the attributes of chemical and biological agents when released in the atmosphere or water. Last, the U.S. requires more accurate wideband radars, multispectral electro-optical sensors, and laser radars to detect ballistic missile launch, to target both cruise and ballistic missiles, and to discriminate missiles and re-entry vehicles from chaff.

A battlefield sensor is part of a larger system. It must perform within the constraints of that system. It is particularly stressing where there is a requirement for very short military reaction to a sensed input, for example to detect and target a closing sea-skimming missile, to detect and target a ballistic missile during boost phase, and to perform friend versus foe identification without degradation of combat reaction time. Sensors are logical, cost-effective candidates for technology insertion and weapons systems upgrades. Both incremental enhancements and breakthroughs must be found in the sensor area.

Conclusion

Three high-priority, DoD-wide technologies have been outlined. However, S&T program will continue to be a broad-based program, spanning all defense-relevant sciences and defense-relevant technologies. The services will continue to field robust programs in service-specific technologies: the Army will continue to invest in terrestrial science and armor materials, the Navy in ocean geophysics and acoustic signature analysis, and the Air Force in atmospheric physics and space launch.

IV. THE SCIENCE AND TECHNOLOGY PROGRAM

The S&T program is traditionally described as having three separate and identifiable elements: Basic Research, Exploratory Development, and Advanced Development. The categories relate more to budgeting and accounting than to execution. The S&T program and the advancement of technology is a continuum, not discrete phases.

The objective of the Basic Research Program is to produce knowledge in a science or engineering area that is militarily relevant. It cannot be known whether a particular scientific result will lead to a military application. While sometimes research pays a dividend with a transition directly from the research laboratory bench to a defense system in the field, more often the full impact of research is not felt until much later.

Basic research is inherently a long-term investment, with emphasis on opportunities far into the future. The basic research program investments are in twelve areas: atmospheric and space sciences, biological and medical sciences, chemistry, cognitive and neural sciences, computer sciences, electronics, materials science, mathematics, mechanics, ocean sciences, physics, and terrestrial sciences. New knowledge from our research program enables smart resource usage and smart expenditure decisions. Not all knowledge and information leads, or is intended to lead, to a new system. For example, better knowledge of ocean thermal dynamics influences how submarines operate so as to minimize detection. Where the transfer of such knowledge does not involve embodiment in a new physical system, it can occur very rapidly.

Universities perform about half of the basic research program. Scientists and engineers at DoD laboratories also perform basic research. A lesser portion of the program is placed in industry, non-profit research institutes, and other federal laboratories. The university research involves graduate students, which produces young scientists and engineers who are familiar with DoD needs.

Exploratory Development and Advanced Development programs mature technologies. In some cases prototypes embodying a technology are built. Exploratory Development provides proof of concept experiments and evaluations built around models and laboratory experiments. The Advanced

Technology Development program is structured to apply technological advances to provide military capability.

Technology efforts are structured into a group of nineteen technology areas for oversight purposes: aerospace propulsion and power; air vehicles and space vehicles; battlespace environments; biomedical; chemical and biological defense; clothing, textiles, and food; command, control, and communications; computing and software; conventional weapons; electronics; electronic warfare and directed energy weapons; environmental quality and civil engineering; human systems interface; manpower, personnel and training; materials, processes and structures; sensors; surface/undersurface vehicles and ground vehicles; manufacturing science and technology; and modeling and simulation.

The Continuum of Technology Exploration

Taking an idea from a fundamental science to application in the hands of the military involves activity across a continuum. Feedback occurs. To highlight the richness of this activity, a hypothetical example is provided of the history of the development of a new material.

A new material developed in a university research laboratory may exhibit characteristics that make it attractive as a means for detecting minute particles that are associated with a potentially lethal chemical substance. The research is documented and reported to the Department of Defense where the results become apparent to scientists who may be working on counter-proliferation issues. Work on the material transitions to Exploratory Development with the goal of determining the conditions—temperature, pressure, humidity, and others—under which the material behaves in a predictable way. If the behavioral envelope is promising and the material performance is appropriate, Advanced Development could be the next logical step where the material is used in the context of a prototype, miniature battlefield sensor.

Research on this material may continue. Many questions may remain. For example, it may be useful to determine the ways which the material can be produced less expensively, more reliably, or more rapidly. It may be made more sensitive, so that it detects smaller concentrations, possibly from greater range. The detection envelope might be broadened or narrowed.

In Advanced Development, the material could be integrated with a mechanical fixture that serves as a sampling mechanism, and electronics that measure the output as well as analyze, record, or transmit the results. This subsystem would be exposed to laboratory and experimental field conditions to evaluate its military utility. For example, it may be too insensitive for use from a space based satellite

or a high altitude reconnaissance aircraft and may not withstand the vibrations from a helicopter. It may not have significant military utility. But, the continuing research efforts may have produced a variation with far greater sensitivity that makes space-based surveillance feasible and would thereby address the counter-proliferation need.

At this juncture the material could be used to upgrade the Defense Support program (DSP) or the Joint Surveillance Target Attack Reconnaissance System (JSTARS), or it could become an element of a counter-proliferation technology demonstration.

Advanced Concept Technology Demonstrations

The objective of the S&T program is to support military needs and to solve military problems, as well as to provide a sound basis for acquisition decisions. Rapid technology transition into the operational forces is crucial. For these reasons, a new aspect of the S&T program has been defined: Advanced Concept Technology Demonstrations (ACTDs).

They are the focused successor to the broad S&T thrusts pursued over the past several years. Where the thrusts were broadly based, ACTDs are tightly focused on specific military concepts. The ACTD provides a mechanism for intense involvement of the warfighters while incorporation of technology into a warfighting system is still at an informal stage. This allows iterative change of both the system construct and the user's concept of operation without the constraints and costs which are incurred when the discipline of formal acquisition is involved.

The ACTDs are user-oriented, even user-dominated. The ACTDs have three motivations: 1) to have the user gain an understanding of and to evaluate the military utility before committing to acquisition; 2) to develop corresponding concepts of operation and doctrine that make best use of the new capability; and 3) to provide residual operational capability to the forces. ACTDs are of militarily significant scope and of a size sufficient to establish utility.

An important element of the ACTDs is that the user is left with a residual operational capability and the wherewithal to continue use. This provides the commander with a significant improvement in capability and the ability to continue to refine the doctrine and tactics to maximize the potential of new technologies.

Requirements of the operational forces will be generated during definition of an ACTD. The outcome of an ACTD is judged by the users. If a user is not prepared to initiate acquisition, the effort will terminate consistent with the user's reasons. If, on the other hand, the user determines that the

demonstrated concept should be brought into the forces, there are two possible avenues. First, if large numbers are required, the system will enter the acquisition process at whatever stage good judgment dictates. Second, if only small numbers are required, it is preferable to modify the demonstration system appropriately and then to replicate it as needed. This latter avenue might apply to command and control, surveillance, and Special Operations equipment, as well as to complex software systems where evolutionary development, with routine upgrades, is preferred.

Management and Oversight

The S&T Program is planned, programmed, and conducted by the Military Departments and the Defense Agencies. The Departments are responsible for training and equipping the military forces; they use the S&T program to provide warfighting and system options for their components. The Defense Agencies are responsible for specified generic and cross-service aspects of S&T. They also execute designated programs in support of national security objectives. It is the Advanced Research Projects Agency that is charged with seeking breakthrough technology, and with investing in technologies that are heavily dual use in nature, that is they serve as a basis for both defense and commercial application.

The Director, Defense Research and Engineering (DDR&E) is responsible for the direction, overall quality, and content of the DoD S&T Program. The DDR&E ensures that the program responds to the needs of the U.S. military and to the national goals embraced in the program's vision. The Deputy Undersecretary of Defense for Advanced Technology is responsible for creation of and oversight of Advanced Concept Technology Demonstrations that speed the use of technology in warfighting systems and ensure that experimental systems are evaluated in a meaningful way by the users. The Services and Agencies meet in Project Reliance where S&T programs are reviewed to ensure that unnecessary duplication is eliminated.

The DDR&E, in collaboration with the Military Departments and Defense Agencies, has prepared a Technology Plan which documents the focus and content of the overall DoD technology effort. Goals, objectives, schedules, and funding are defined for each of the nineteen technology areas identified above. The Technology Plan also discusses opportunities for transitioning technology rapidly into fielded systems, and projected operational payoffs. The Technology Plan will be used to ensure that component efforts are responsive to the *overall* DoD strategy and vision. The Technology Plan will be adapted, as appropriate, annually.

In each technology area, a Detailed Technology Plan is maintained as a working document. Components executing programs and projects maintain the most detailed plans.

V. GUIDING PRINCIPLES FOR SCIENCE AND TECHNOLOGY MANAGEMENT

The S&T program needs to be grounded in a deep understanding of fundamental science, and a broad-based understanding of technology and how it is evolving. In this context, options for dramatic new military capabilities can be recognized and exploited, and the U.S. can anticipate and counter unexpected developments in the capabilities of potential adversaries.

While technological superiority remains a guiding objective, the new world demands a more balanced approach to technology, product, and process development. Lower budgets increase the emphasis on affordability, longer lived weapon systems, and evolutionary insertions of new technology into existing systems. Reduction of costs is an important exit criteria as technology transitions to fielded systems. The health of the defense industrial base also requires increased attention; DoD is supporting commercial-military industrial integration by developing dual use technology, where appropriate. Close connection with the science community outside DoD is crucial to assure scientific progress in military-relevant fields.

All this places new demands on and requires new approaches for the management of S&T resources. Five guiding management principles have been adopted by the Military Departments and Defense Agencies. These management principles are designed to place in the hands of our operational forces the best mix of capabilities possible, in the short and long term, by leveraging the best resources in DoD and the nation:

1. Transition Technology To Address Warfighting Needs
2. Reduce Cost
3. Strengthen the Commercial-Military Industrial Base
4. Promote Basic Research
5. Assure Quality

The remainder of the document discusses each of the principles, highlighting management actions being taken.

1. TRANSITION TECHNOLOGY TO ADDRESS WARFIGHTING NEEDS

Develop and Transition Superior Military Technology

Because of the nature of the Cold War, our former S&T program was challenged to produce weapons that were capable of countering a numerically superior, sophisticated enemy. Technology was driven by a need to counter a capable Army with large armor, artillery, and infantry forces; a formidable Navy, both on and below the surface, and an Air Force that introduced new high performance fighter and strategic aircraft on a frequent, but predictable, cycle.

Today's challenge is to increase the warfighter's access to new capabilities at a fraction of the cost of prior approaches. New capabilities must be provided on time scales consistent with commercial technology turnover. Above all, technology options must support military needs and solve military problems, including meeting new threats and serving new missions. It is imperative to avoid technological surprise, which historically derives from the integration of technologies into dramatic new strategy and tactics.

Work With The Warfighters. It is the warfighters who must determine what capabilities are needed and therefore what technologies to develop. When technologies have emerged from the laboratory, technologists work with users to articulate capability needs matched with technology opportunities. That is the basis for defining the new Advanced Concept Technology Demonstrations (ACTDs). Jointly planned by users and technologists, an ACTD enables operational forces to experiment in the field with new technology in order to evaluate potential changes to doctrine, operational concepts, tactics, modernization plans, and training. The field environment provides as much realism and surrounding context as is possible. ACTDs provide a basis for sound and reasoned acquisition decisions, and assured understanding of performance, cost and schedule risks.

Move Promising Concepts Rapidly. The various stages of the DoD S&T program are a continuum. Typically, a new concept arises from research, crystallizes into a technology that can be explored in the laboratory, and lastly becomes a technology that can be transitioned into a military system. There is a premium on moving rapidly through this continuum.

Insert Technology Into In-Service Systems. Technology moves fastest if it can move out of the laboratory to an already fielded system. When the opportunity arises, new, but mature, technology can be inserted as an upgrade to a system in service. Particularly amenable to direct transfer from the lab to an existing system are information and electronics technologies that can enhance capability with the replacement of computers, communications, and software.

Prevent Technological Surprise. Technological surprise historically occurs when new technology is employed with a surprising concept of operations. The global arms market transfers new weapon systems to any nation that can pay for them. The U.S. needs to be vigilant to guard against surprise. This requires good intelligence on weapons availability and military concepts of potential adversaries. It also requires that the U.S. S&T community maintain a continuing awareness, through its own scientific investigation, of emerging technology that could have military application. Defense scientists and engineers must understand the potential of emerging technologies and be poised to react rapidly to an innovative use of technology by potential adversaries. ACTDs will speed consideration of alternative operational concepts for U.S. employment of new technology.

2. REDUCE COST

Reduce Weapon and Support System Life Cycle Costs

Throughout the Cold War, the dominant objectives of S&T were to achieve higher performance and to invent new functional capability. Now, with the DoD procurement budget reduced by about two thirds from 1985 to 1995, it is critical that the S&T program adopt cost reduction in current and future weapons and support systems as a primary objective.

The cost of ownership—operation, maintenance, evolutionary upgrade, and de-militarization—is greater than the cost of acquisition for most systems. Thus, full life cycle costs must be considered during the technology development and demonstration phases; consideration cannot wait until product development. Because 80 percent of the life cycle cost of a system is normally determined by the investment of the first 5 percent of the life cycle costs—i.e., during the concept and preliminary design phase—affordability must be a key technology and design objective.

Use the Best Commercial Products, Practices, and Capabilities. The Defense Department must exploit national and international commercial practices, standards, technologies, products, and protocols as the rule, rather than the exception. Scientists and engineers in the S&T program need to be cognizant of this even as they are making tradeoffs in the laboratory. Similarity in the technology and products for defense and commercial applications can reduce the time to reach productization, and can reap benefit from the economies of scale that derive from commercial, mass markets. Where defense needs unique items, the objective is to manufacture them on flexible production lines.

There are an increasing number of cooperative relationships between the DoD laboratories and industry, such as the Cooperative Research and Development Agreement between the Army Tank and Automotive Command and Ford, General Motors and Chrysler. Such relationships set the scene for increased knowledge of and reliance on commercial practices. Where appropriate we must guard against the proliferation of defense technology which is critical to our military superiority.

Simulate. Simulation has come of age. It offers promise as a tool during the technology development process as well as during the setting of

requirements and acquisition. Automated simulation technology provides a richer context than is otherwise possible, thereby allowing technologies to be evaluated under a broad set of conditions. Use of simulation allows technologists and warfighters to collaborate earlier in the development process, and provides users the means for a more thorough evaluation of concepts. Simulation can provide improved cost-benefit analyses, better requirements, more comprehensive performance trade-off analyses, more producible designs, and more productive testing. Simulation can result in substantial cost reductions.

Improve Manufacturing Processes. Manufacturing as practiced in the United States is undergoing rapid changes to reduce cost, enhance quality, and add new capability in terms of flexibility and agility. The Defense Department must continue to invest in accelerating this change and capitalizing on it for defense needs. Metrics are not only reduced cost to manufacture and reduced cost for low rate production, but a shorter design and engineering phase, earlier detection and correction of manufacturing difficulties, reduced test and evaluation time, reduced defect per manufacturing lot, and rapidly adaptable manufacturing lines. A broad program is being pursued. Efforts include 1) easily reconfigurable manufacturing equipment to allow economical, variable-volume lot runs; 2) integrated product and process development that permits production analysis during product design and the tailoring of both the product and the process; and 3) cost reduction of the combination of technology and manufacturing.

Consider Environmental Factors. Life cycle cost includes environmental costs—from pollution prevention during manufacturing to clean-up of bases, depots, and ranges. Environmental law compliance and environmental restoration costs are growing rapidly, particularly as the Defense Department seeks to return closed base property to communities. DoD has an S&T program to develop and harness technologies to reduce the production of pollutants, reduce the cost of environmental clean-up and restoration, destroy munitions and systems in a more environmentally benign way, and isolate environmentally hazardous substances more reliably, at less cost, and for a longer time. The S&T program is developing tools, to be included in life cycle cost models, that will address environmental issues early in the design phase of new systems.

Establish Service Affordability Programs. Each Service has had a menu of individual S&T efforts addressing affordability issues. The Services will now integrate and strengthen these into a coherent program that emphasizes Service-unique needs and addresses the broad spectrum of affordability challenges.

Reduce the Cost of Ownership. DoD must search out technology and technology applications that reduce the cost of operating, maintaining, and upgrading systems. This includes embedded corrosion and fracture sensors, non-destructive testing techniques, effective lubrication substances, and improvements in the speed and effectiveness of diagnostic tools.

3. STRENGTHEN THE COMMERCIAL-MILITARY INDUSTRIAL BASE

Use The Same Technology And The Same Industrial Base, Where Appropriate, To Build Military And Commercial Products

DoD needs the aggressive technology maturation rates and the cost reductions that come with mass production. In times past DoD developed its own technology, or its own version of non-defense technology, for use in military products. It paid to define and sustain a defense industry partially set apart from civilian industry.

Today, that strategy is not practical. In addition, technologies critical to achieving future advances in military capability are increasingly developed by civilian industry—both inside and outside the United States—in key sectors such as computers, electronics, advanced materials, and biotechnology. In some areas, national and international research and development investments outside Defense dominate DoD investment. DoD must monitor and exploit these advances.

It is an S&T objective to use the same technology and the same industrial base, where feasible, to build military products and commercial products. The goal of the S&T program is to achieve military technological superiority in a fashion that serves both classes of products.

Develop Dual Use Technologies and Processes. Dual use refers to technologies, processes, and products with both military and non-military applications. A technology or process may first be developed for a military context and then be applied to commercial use, or vice-versa. Commercial and military application may be pursued in parallel. All paths lead to dual use applications. The S&T program will be managed to nurture both kinds of applications.

It is imperative that DoD foster, to the maximum extent practical, an integration of the military and commercial industry in order to achieve a more cost-effective, single set of industrial enterprises that are capable of developing and building more affordable and productive military and commercial products. The defense S&T investment can be made so as to contribute to this

integration by preferentially developing technologies that have dual use, when that is possible.

The majority of the S&T investment is already made in dual use technologies and processes. DoD has a long history of sustained investment both in technology development and in industrial process maturation that directly contributed to commercial economic growth and job creation. This has been one of the strengths of the DoD S&T program. Today, the best known defense program fostering dual use is the Technology Reinvestment Project, led by the Advanced Research Projects Agency (ARPA). It is a multi-agency program with projects whose execution is being overseen by the Services, ARPA, and other governmental agencies.

An important caveat is that there will remain some critical, defense-unique technologies and industries, such as nuclear weapons, the acoustic quieting of submarines, and missile guidance. DoD must bear the cost and the responsibility for advancing these technologies and nurturing the research and development component of those industries.

Formalize Each Service's Program In Dual Use. Each service will develop formal, targeted, dual use programs to develop technologies critical to the needs of that service. Particular attention will be paid to areas where the defense industry is converting to dual use product manufacturing and where the defense industry may retract to the point that the supply of critical products is in jeopardy.

Sustain Investment In Priority Technologies. Another strength of the S&T program has been its ability to sustain an investment from the birth of a technology until it has matured as the basis for a substantial and stable industry. This must be continued. The DoD investment in electronics provides one example. Since the 1960s DoD has invested in micro-electronics. In 1965 DoD purchased more than 50 percent of the semiconductors manufactured in the U.S. Today DoD purchases less than two per cent of a much larger market. Industrial research and development investment in this area now dwarfs that of DoD. However, DoD made crucial early, long-term investments in micro-electronics technology and fabrication process maturation that industry, with a shorter term investment horizon, could not make. DoD's investment has paid dividends many times over, not just for the military, but for the country.

The Department of Defense will continue to make sustained S&T investments in the most militarily relevant dual use technologies to the extent that its budget permits. Its own need to exploit a technology guides that investment. Because the DoD is both an investor in science and technology, and also a consumer of the derivative products, it has excellent insight into what

technologies are most promising from a military perspective. Because benefit is not realized by the military until products are achieved, the DoD has both the motivation for a sustained investment and the basis for judgment of whether progress is being made toward achieving acceptable military products.

Exploit Commercial Technologies. There is an increased opportunity to meet defense needs by adopting commercial technology and commercial products, such as electronics, software, and communications. The service laboratories must monitor commercial product offerings and be the catalyst for the adoption of such products where they offer advantages.

Strengthen Technology Transfer. Each Service will establish a program that fosters dual use technology development, ensures exploitation of commercial technology, and nurtures technology transfer between in-house laboratories, industry, and university and not-for-profit laboratories. It is expected that there will be an increase in the shared use of facilities by the Service laboratories and industry. Participation in regional, state, and local alliances will be encouraged. A change in service laboratory culture is required, and has already started to occur, as evidenced by the increase in laboratory collaborations with industry using Cooperative Research and Development Agreements.

Field Selected Initiatives to Apply Technology to Societal Needs. DoD will identify economic and societal needs where it has special ability to lead in the application of technology. These needs include health care, environment, aviation, energy, and information systems. Prototype services and applications will be built. ARPA has fostered many technologies that today provide the opportunity to create the National Information Infrastructure. ARPA will prototype selected high priority information infrastructure applications.

4. PROMOTE BASIC RESEARCH

Expand Fundamental Scientific Knowledge That May Lead To Future Warfighting Capabilities

Technological superiority is grounded in scientific knowledge. DoD invests broadly in defense relevant scientific fields. The objectives are first, to discover new knowledge, and second, to sustain a community of expert scientists who exploit new knowledge as they seek superior, new warfighting capabilities. By its very nature, basic research potentially applies to both military and non-military needs. Thus, the DoD basic research program supports both economic security and national security.

Support Quality Basic Research. As new ideas emerge, only those who have a deep, long-lived involvement in clarifying those ideas fully understand them and have an opportunity to recognize their potential application. DoD requires a basic research program to assure that it has early cognizance of new scientific ideas. It is not usually possible to predict precisely what knowledge will eventually be of value. The Department of Defense sustains its investment in basic research because of proven experience of significant, long term benefits to the military. Research provided the foundation for our technological superiority in each of our recent conflicts. Radar made a material contribution to winning World War II. Stealth, electronics, and computers played a major part in recent warfare.

Because basic research is essentially an exploration of the unknown, it is important that it be conducted by the highest quality people. The DoD involves first-rate scientists found in universities, industry, defense laboratories, other government laboratories, and the Federally Funded Research and Development Centers. The program will be managed to support the best researchers, regardless of organizational location. Merit based selection of projects will ensure quality.

Sustain Stable Research Funding. Research typically requires many years to reach fruition. In this time of precipitous budget change, it is incumbent on the science and technology management to ensure stable funding for the highest priority efforts. Disruption of a research project is difficult to reverse. For example, research efforts that revolve around a few individuals typically cannot be restarted if even a few of the individuals depart.

Educate Future Scientists and Engineers. The country and DoD require a steady influx of educated scientists and engineers with an interest in and knowledge of defense problems. To ensure that this supply of technical talent will continue, DoD sustains its long-standing commitment to support students studying science and engineering. It will continue the small, but important, programs to bring students to the defense laboratories on cooperative or other arrangements in order to involve them first-hand in defense problems. To make full use of the potential of U.S. citizens, DoD will continue to strengthen the scientific capability of the colleges and universities with significant student enrollments from minorities underrepresented in science and engineering. DoD will provide science-related infrastructure, as well as funding for defense research and engineering programs.

Promote Teamwork and Partnerships. The DoD basic research program fosters teamwork and partnerships of many forms: defense laboratory researchers teaming with in-service materiel engineers in the labs to explore jointly the symptoms of component failure; defense lab scientists teaming with university or industrial scientists, perhaps drawn together to share use of lab equipment or instruments; consortia of universities and of universities and industry; and allies. The program seeks to not only value tradition, but to encourage and embrace innovative change.

There is also a mutual dependence between DoD and other government science and technology organizations. Nurturing and leveraging this extended community has taken on increased importance in recent years. DoD relies upon NASA for the development and testing of some space-bound systems, the National Oceanographic and Atmospheric Administration for weather information, and DoE for nuclear weapons. The Technology Reinvestment Program also involves close coordination between DoD and other government agencies.

5. ASSURE QUALITY

Assure That Excellent Scientists And Engineers, Supported By First Rate Facilities, Continue To Develop Superior Military Technology

Quality is more important than quantity in the execution of the S&T program. It is more productive to have fewer, but better scientists and engineers, and fewer, but better facilities. This holds true for work performed inside the defense laboratories, as well as that contracted outside. The DoD Science and Technology leaders must accept the challenge to take action to assure quality in the post-Cold War environment.

Downsize, Outsource, and Restructure the DoD RDT&E Infrastructure. Budget reductions, particularly those in the procurement and modernization accounts, require reduction of the Research, Development, Test, and Evaluation (RDT&E) infrastructure of which the S&T infrastructure is an integral part. These include the DoD laboratories; research, development and engineering centers; test centers; university centers, federal laboratories, Federally Funded Research and Development Centers (FFRDCs); non-profit corporations; and even industry. Reductions in people, facilities, and sites must be made very carefully. The S&T infrastructure itself, with its ability to act and react, is an important product of the RDT&E program. Those portions that are critical to our future must be retained, restructured as necessary, strengthened, and sized so as to be supportable with future defense budgets. DoD must reassess the conditions under which it maintains in-house technological capability. Today it may be more effective to rely on industry or universities for those technologies that are developing outside DoD at a rapid pace.

DoD will use the schedule and mechanisms provided by the 1995 Base Realignment and Closure Commission process in this restructuring. The DoD goal is to eliminate unnecessary redundancy and low value-added activities. Some savings must be reinvested to improve quality and capabilities. The restructuring, downsizing, outsourcing, and reinvestment should ensure that the smaller in-house laboratory complex emerges stronger and of higher quality.

Retain a Critical Mass of Internal Expertise. Core competencies in militarily relevant technologies must be maintained in order to support product

development, acquisition, evolutionary upgrades of existing materiel, and crisis response. Some technologies, such as acoustic damping for submarines, mine detection and neutralization, missile guidance, nuclear weapons effects, and some aspects of high performance optical systems are uniquely and exclusively military. DoD must maintain in-house expertise and facilities in such areas. There are other technologies where increased reliance on industry is desirable and appropriate.

Encourage Innovation. First-rate scientists and engineers with the leeway to investigate high risk, high value opportunities, without fear of failure will innovate. And innovation can move technology forward with great speed. By their very nature, many experiments and explorations change course or run into dead ends due to unforeseen developments and discoveries. Innovative exploration is risky and unpredictable in outcome. The S&T leadership is responsible for encouraging innovation while at the same time allocating resources prudently.

Strengthen Project Reliance. The Services have become increasingly interdependent. This will increase by design. Project Reliance is an important vehicle for ensuring that the research efforts of the services and agencies are fully coordinated and not duplicative. Under this program, bench level scientists and engineers work with their colleagues from other organizations, sharing research results and coordinating future research plans. The next step in the maturation of the several year old Reliance process is to use it as a mechanism to assist DDR&E in planning the S&T program: Reliance is playing a major role in the development of the DoD Technology Plans.

Enhance the Quality of Staff and Facilities. As DoD laboratories become smaller, an even greater premium must be placed on ensuring the excellence of the people, the facilities they work in, and the equipment they use. DoD will size its laboratories so that future budgets are adequate to recruit and retain top scientists and engineers, and to maintain and operate modern facilities and equipment. Recent efforts to improve laboratory quality include: improved contracting procedures; more effective control of laboratory facility management; discretionary budgets for laboratory technical directors; stability of technical directors; and improved personnel practices for scientists and engineers. Some progress has been made.

Bureaucracy and the personnel system rules force disadvantageous action. Consequently, part of the laboratory restructuring effort will include attention to legislative changes necessary to permit more effective and efficient laboratory management. The National Performance Review opportunities will be used. DoD will continue to apply, across the entire S&T community, the best practices for evaluating the stewardship of S&T resources, through the use of peer reviews, benchmarking, and other metrics. DoD scientists must

be second to none. Professional education, publications, and other forms of scientific recognition are some metrics of research staff quality. Innovation will continue to be stimulated and rewarded, and risk-taking will be encouraged.

Monitor and Collaborate In International Science Efforts. No longer does the U.S dominate world science and technology. Those who participate in the DoD S&T program need to monitor the emergence of new scientific ideas and the development of mature technologies internationally. Important reported experiments should be replicated. Where appropriate, we need to increase collaboration with allies, including countries of the former Soviet Union, to ensure that those performing S&T work remain at the leading edge.